Document title:	**TWRS-P Facility Design Basis Earthquake – Peak Ground Acceleration, Seismic Response Spectra, and Seismic Design Approach**
Department:	Safety & Regulatory Programs
Contract title:	TWRS Privatization
Contract number:	DE-AC06-96RL13308
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Document Number:	RPT-W375-RU00002, Rev. 1
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Date of issue:	March 17, 1999
Issue status:	Approved
Approved by:	Don Edwards
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History sheet

Rev	Date	Reason for revision	Revised by
0	12/14/1998	Initial Issue	
1	03/17/1999	Revised to incorporate DOE RU comments	Richard Smith

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1. Introduction

The TWRS-P Facility processes and stores radioactive and hazardous materials. Consequently, it is necessary to ensure that the facility can provide an adequate level of safety to facility workers, co-located workers, and the public while also providing protection to the environment. One of the steps to achieving this is to design selected important-to-safety SSCs to withstand the effects of severe natural phenomena events such as earthquakes. To that end, this document:

- Describes the process used to select a seismic standard for the TWRS-P Facility design and identifies the specific seismic standard selected (Section 2.0)

- Applies that seismic standard to establish the peak ground acceleration (PGA) for the TWRS-P Facility Design Basis Earthquake (DBE) and presents the seismic response spectra that will be used to help determine the TWRS-P Project design response spectra (Section 3.0)

- Describes, in general terms, the approach to be used for performing TWRS-P Facility seismic design for the DBE (Section 4.0).

Revision 0 of this document was issued to the DOE Regulatory Unit (RU) in support of a Topical Meeting on seismic issues that was held on December 14, 1998. This revision addresses comments and questions from that meeting as well as comments and questions from two earlier Level 1 Meetings with the RU that were held on November 6, 1998 and December 3, 1998 and from a meeting with Geomatrix Consultants on January 7, 1999.

The RU's written comments and questions are identified in Section 5.0, which includes either explicit responses or cross-references to where responses may be found. Where appropriate, responses to some of the RU's comments and questions also appear within the text of this report.

In addition to this report, there are four other related documents being prepared by BNFL Inc. These documents, which include the balance of the responses to the RU's comments and questions, are as follows:

- Applicability of DOE Documents to the Design of the TWRS-P Facility for Natural Phenomena Hazards

- Validation of the Geomatrix Hanford Seismic Hazard Report for Use on the TWRS-P Project

- Approach for Ensuring Compliance with the TWRS-P Project Radiation Exposure Standards Under Earthquake Conditions

- TWRS-P Facility Seismic Design Criteria.

The first three related documents are being issued to the RU concurrently with this report; the seismic design criteria document is forecast for issue to the RU at the end of May 1999.

2. Selection of Seismic Standard

The selection process for identifying a seismic standard for the TWRS-P Facility design is summarized below. This process reflects the approach given in *Process for Establishing a Set of Radiological, Nuclear, and Process Safety Standards and Requirements for TWRS Privatization* (DOE/RL-96-0004 [DOE-RL 1996a]) as implemented by the *Implementing Standard for Safety Standards and Requirements Identification* given in Appendix A to Volume II of the Safety Requirements Document (SRD, BNFL Inc. 1998a). For purposes of this document, only the first six steps of the seismic standard selection process are described.

2.1. Step 1 - Process Initiation

For the TWRS-P Project, this step has already been achieved as part of the implementation of the overall standards identification process.

2.2. Step 2 - Identification of Work

The work to be performed is the handling, processing, and storage of highly radioactive materials and hazardous chemicals.

2.3. Step 3 - Hazards Evaluation

The principal hazardous situation associated with a seismic event is an uncontrolled release of radioactive materials and hazardous chemicals due to the failure of SSCs. Because of the large quantities of these materials that are present in the facility, the potential unmitigated consequences of such an event can be significant. In fact, these unmitigated consequences, as shown by analyses reported in the TWRS-P Project Part A *Initial Safety Analysis Report* (ISAR, BNFL Inc. 1998b), are likely to be in excess of the exposure standards for the TWRS-P Project as defined in Section 2.0 of Volume II of the SRD (BNFL Inc. 1998a).

2.4. Step 4 - Development of Control Strategies

Because there is no way of preventing an earthquake, preferred hazard control strategies consist of maintaining confinement by preventing or mitigating the failure of SSCs during a seismic event. This is achieved by ensuring that specifically identified SSCs are designed and constructed such that these SSCs can withstand the effects of a DBE without loss of their ability to perform their necessary safety functions.

At the current stage of design evolution, the hazard control solution, i.e., the identification of the specific SSCs which must survive the DBE, has not been completed. Preliminary evaluations based on analyses reported in the TWRS-P Project Part A ISAR (BNFL Inc. 1998b) indicate that the most likely candidates include:

- Selected segments of the primary confinement barrier; specifically, those tanks and vessels containing either significant quantities of highly radioactive materials or significant quantities of hazardous chemicals (passive feature)

- Selected segments of the secondary confinement barrier; specifically, the facility structures housing the major radioactive processes and process vessels (passive feature) and the C5 Extract System (fans, filters, ductwork, power, and controls) which exhausts and filters the process cells (active feature).

In addition to the above, other potential candidates include the Process Vessel Vent System and the HLW Melter Off-gas System which exhaust and filter the pretreatment process vessels and the HLW melters, respectively (active features).

2.5. Step 5 - Identification of Standards

Although the specific SSCs in the control solution have not been identified, there is sufficient information to select the appropriate seismic design standard. (Note: The TWRS-P Project PSAR, when issued, will identify specific control solutions).

Documents reviewed as candidates for the standard to establish the TWRS-P Project design criteria for the DBE include:

- DOE-STD-1020-94, Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities (DOE 1996a)

- 10 CFR 100, Reactor Siting Criteria

- 10 CFR 72, Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste

- Federal Register Notice 53 FR 13276, Advanced Notice of Proposed Rulemaking – Regulation of Uranium Enrichment Facilities.

These documents are listed in Revision 0 of the TWRS-P Project SRD under the “Equivalent Standards Reviewed” heading for Safety Criteria 4.1-3 and 4.1-4. The “Equivalent Standards Reviewed” field was subsequently deleted in Revision 1 of the SRD (BNFL Inc. 1998a).

The standard selected is DOE-STD-1020-94 (DOE 1996a). The bases for the selection of this document as the seismic standard for the DBE are given below.

- The DOE-STD-1020-94 (DOE 1996a) seismic design criteria specify seismic loading in probabilistic terms. This probabilistic characterization allows direct and explicit incorporation of seismic loads into a safety analysis procedure, including rigorous consideration of uncertainties in design loads and, ultimately, a state-of-the-art and stable estimate of earthquake risks associated with the facility. The approach also allows quantitative comparisons of the relative risks posed by facilities of significantly different potential failure consequences ranging from structures whose failure would endanger only its occupants to SSCs, like those of a nuclear reactor, whose failure could have wide-ranging and long-term consequences.

- DOE-STD-1020-94 (DOE 1996a) utilizes a graded approach. It controls the level of conservatism in the design/evaluation process such that: (1) the hazards are treated consistently; and (2) the level of conservatism is appropriate for SSC characteristics related to safety, environmental protection, importance, and cost.

- DOE-STD-1020-94 (DOE 1996a) presents detailed criteria for the design or evaluation of all classes of structures, systems, and components for earthquake ground motion. It specifies how to establish DBE loads on various classes of SSCs; how to evaluate the response of SSCs to these loads; and how to determine whether that response is acceptable. It also covers the importance of design details and quality assurance to earthquake safety. These earthquake provisions are applicable to buildings and to items contained within the buildings.

- DOE-STD-1020-94 (DOE 1996a) provides an integrated and self-contained approach in which all elements of earthquake design are considered together to assure acceptable performance of all facility SSCs.

- DOE-STD-1020-94 (DOE 1996a) is approved for use by all departments and contractors of the Department of Energy. It has been successfully applied at DOE facilities including ones recently built and others currently under design or construction. These include the Device Assembly Facility at the Nevada Test Site (construction complete), the Canister Storage Building and Cold Vacuum Drying Facility at Hanford (both nearing completion), and the Actinide Packaging Storage Facility at the Savannah River Site (under construction).

As noted in its introduction, DOE-STD-1020-94 (DOE 1996a) is part of a hierarchy of documents that specify the requirements for protecting DOE facilities from the impacts of natural phenomena hazards. For purposes of this document, only the seismic provisions of DOE-STD-1020-94 (DOE 1996a) are being adopted for the TWRS-P Project. The related document identified in Section 1.0 (“Applicability of DOE Documents to the Design of the TWRS-P Facility for Natural Phenomena Hazards”) identifies the specific applicability of DOE-STD-1020-94 (DOE 1996a) and the other documents in the hierarchy to the TWRS-P Facility design.

2.6. Step 6 - Confirmation of Standards

This document and its supporting material have been provided to the TWRS-P Project Safety Committee. The Committee has reviewed the material and its comments and findings have been incorporated.

3. Application of the Selected Seismic Standard

As noted in Section 2.0, DOE-STD-1020-94 (DOE 1996a) employs a graded approach “to ensure that the level of conservatism and rigor in design … is appropriate for facility characteristics such as importance, hazards to people on and off site, and threat to the environment.” To that end, DOE-STD-1020-94 (DOE 1996a) assigns seismic criteria to SSCs by placing them in one of five Performance Categories ranging from PC-0 to PC-4. The specific Performance Category (PC) assigned to an SSC is dependent on the safety classification of the SSC which, in turn, is based on the SSC's safety function in accident prevention or mitigation.

From a safety analysis standpoint, a large earthquake (such as a DBE) is normally assumed to fail or degrade all SSCs not designed to withstand the loads from such an event. DOE-STD-1020-94 (DOE 1996a) directs that PCs be assigned using the approach described in *Natural Phenomena Hazards Performance Categorization Guidelines for Structures, Systems, and Components* (DOE-STD-1021-93 [DOE 1996b]). It should be noted that the single performance category selected for seismic categorization will not apply to each and every SSC at the TWRS-P Facility. This is explicitly recognized in DOE-STD-1020-94 (DOE 1996a) which states that safety classifications – and therefore PCs – “should be applied to specific SSCs on a case-by-case basis and need not apply to an entire facility.”

The performance categorization process is shown in Figure 2-1 of DOE-STD-1021-93 (DOE 1996b). In this process, the first check is against PC-4 guidelines. If the SSC is not PC-4, it is then evaluated against PC-3 guidelines, and so on. The standard assigns PC-4 to SSCs whose failure during a seismic event could result in an off-site release consequence greater than or equal to the unmitigated release from a severe accident at a large (greater than 200 MW_t) reactor. The preliminary analyses reported in the TWRS-P Project Part A ISAR (BNFL Inc. 1998b) indicate that this is not the case for the TWRS-P Facility, so it is not PC-4.

The guidance for a PC-3 categorization is that the SSCs failure could result in adverse release consequences greater than SSC Evaluation Guidelines limits. For the TWRS-P Facility, these SSC Evaluation Guidelines limits are taken to be the radiological and chemical accident exposure standards presented in the SRD (BNFL Inc. 1998a). In this case, the preliminary analyses reported in the TWRS-P Project Part A ISAR (BNFL Inc. 1998b) indicate that it is possible these standards could be exceeded by an unmitigated release following a seismic event. Therefore, the TWRS-P Facility is initially assigned a PC-3 categorization.

The performance categorization guidelines of DOE-STD-1021-93 (DOE 1996b) for PC-3 SSCs also state that, for new facilities, a PC-4 categorization may be desirable “since it may not cost too much more to design the facility as PC-4 instead of PC-3.” An order-of-magnitude cost estimate for the TWRS-P Facility indicates that designing and constructing those SSCs that have a seismic safety function to PC-4 requirements rather than PC-3 could result in additional costs of $70-$80 million (see Table 1 for cost estimate details). Because the potential radiological consequences of a seismic event at the TWRS-P Facility are not large (as shown by the analyses reported in the TWRS-P Project Part A ISAR [BNFL Inc. 1998b]), the seismic risk of the facility is relatively low. Consequently, the seismic risk reduction resulting from a PC-4 categorization does not justify the large cost increase, and a final performance category of PC-3 is assigned.

Given that the TWRS-P Facility is categorized as a PC-3 facility, a return period of 2,000 years is established for the DBE in accordance with Table 2-1 of DOE-STD-1020-94 (DOE 1996a). The next step is to determine the 2,000-year recurrence interval peak ground acceleration and the seismic response spectra to be used in the TWRS-P Project seismic design.

A seismic hazard analysis was recently completed for the DOE-controlled areas on the Hanford Site (Geomatrix 1996). *Seismic Exposure for the WNP-2 and WNP-1/4 Site* (Power et al. 1981) documents a previous Site seismic hazard analysis performed for the Washington Public Power Supply System. Application of the analysis findings to the DOE-controlled areas on the Hanford Site is documented in *Evaluation of Seismic Hazard for Nonreactor Facilities, Hanford Reservation, Hanford, Washington* (Woodward-Clyde Consultants 1989). The Geomatrix Report (1996) incorporates seismo-tectonic data and interpretations that postdate the Power et al. (1981) and Woodward-Clyde Consultants (1989) assessments.

The probabilistic seismic hazard analysis (Geomatrix 1996) was performed by Geomatrix Consultants, Inc. for the Westinghouse Hanford Company to meet the requirements of DOE-STD-1020-94 (DOE 1996a). Geomatrix was chosen to do this work because the principal investigators have an international reputation in probabilistic seismic hazard analysis. In addition, they were familiar with the geotectonics of the Hanford Site and surrounding area, having worked extensively on siting and licensing studies, including probabilistic seismic hazard assessment for the Washington Public Power Supply System.

The Geomatrix Report (1996) has been extensively reviewed by Westinghouse Hanford Company (WHC), independent experts, and the DOE. Input and reviews of the Geomatrix Report included:

- Independent review by WHC geotechnical staff not working on the study

- Review and input from Battelle PNNL staff
- Review and input from the Washington Public Power Supply System geologist
- Independent reviews by an off-site international ground motion expert and an off-site national geology expert
- Independent WHC safety review
- Review by DOE-Richland and DOE-Headquarters geotechnical and safety staff
- Review by DOE-Headquarters external seismic expert panel which included international experts in ground motion, probabilistic hazard analysis, structural design and analysis, and seismic hazards
- Review by Defense Nuclear Facility Safety Board consultants.

DOE-RL (1997) approved the Geomatrix Report for use on the Hanford Site.

In addition to the above, The Geomatrix Report was further validated for use on the TWRS-P Project through a review by geotechnical experts on the BNFL Team. The related document identified in Section 1.0 (“Validation of the Geomatrix Hanford Seismic Hazard Report for Use on the TWRS-P Project”) contains the details and results of this review.

Finally, an independent review of the Geomatrix Report was performed by Dr. Allin Cornell of Stanford University. In the summary of his review (Cornell 1999), Dr. Cornell states “I consider [the Geomatrix Report] appropriate for its intended application to design of important, potentially hazardous facilities at the [Hanford] site.”

A brief discussion of the Geomatrix Report is given in the balance of this section.

The Geomatrix (1996) study considers all known potential sources of earthquakes that might contribute significantly to ground motion hazard estimates at the Hanford Site. These sources include shallow crustal sources near the site and more distant sources associated with the subducted Juan de Fuca plate.

Potential shallow crustal seismic sources determined to be major contributors to the seismic hazard in and around the Hanford Site are as follows:

1. Fault sources associated with major anticlinal ridges of the Yakima Fold Belt (YFB).
2. Shallow basalt sources that account for the observed seismicity in the Columbia River Basalt Group (CRBG) and not associated with YFB faults.
3. Crystalline basement sources.

The mean seismic hazard curve for the 200 East Area is shown in Figure 1. From Figure 1, the peak ground acceleration for a 2,000-year recurrence interval (mean annual frequency of $5x10^{-4}$) is shown as 0.24 g.

It should be noted that this acceleration is different than the value of 0.26g for the 200 East Area given in HNF-PRO-97 (Numatec 1997). This is because HNF-PRO-97, which is also based on the Geomatrix

(1996) report, applies the more conservative 200 West Area seismic criteria uniformly to the 200 East, 200 West, and 100 Areas for consistency of use by Hanford Site contractors.

For the TWRS-P Project, BNFL Inc. has elected to use the 0.26g value for the DBE peak ground acceleration. This decision is based on several factors including:

- Consistency within the 200 Area of the Hanford Site. The change to 0.26g reduces the likelihood that the issue of inconsistent seismic design criteria could surface as an issue relative to the TWRS-P Facility.

- The increase in PGA provides a slight increase in the margin of safety. This is consistent with the TWRS-P Project top-level safety principles given in *Top-Level Radiological, Nuclear, and Process Safety Standards and Principles for TWRS Privatization Contractors* (DOE/RL-96-0006 [DOE-RL 1996b]).

- Low differential cost. The increase in the PGA will have a minimal effect on the cost of systems, structures, and components designed to meet DBE requirements.

The shaking hazard for short period motions (with periods of less than 1-2 seconds) is dominated by contributions from shallow crustal sources near the Hanford Site. Of the shallow crustal sources, structures of the Yakima Fold Belt contribute most significantly to Hanford Site shaking hazard. Figure 2 illustrates contributions of individual YFB folds to the mean seismic hazard at the 200 East Area.

The Cascadia subduction zone lies along the west coast of Washington. Two seismic sources are associated with this zone: very large interface earthquakes between the Juan de Fuca and North American plates (approximately 385 km or more from the Hanford Site), and intraslab earthquakes within the subducted Juan de Fuca plate.

Both interface earthquakes of the Cascadia subduction zone and shallow crustal sources near the Hanford Site contribute to the shaking hazard for longer period motions (with periods greater than 1-2 seconds). For longer period motions, interface earthquakes of the Cascadia subduction zone are the dominant contributors.

In addition to seismic sources, selection of strong ground motion attenuation relations has a significant impact on earthquake hazard analyses. No strong motion data is available for the Hanford Site. Attenuation models developed from empirical strong motions recorded in California were selected as appropriate by Geomatrix (1996) and confirmed by comparison of site response characteristics of the soils underlying the 200 East Area with those represented in the California empirical strong motion database.

Equal-hazard response spectra for the 200 Area, shown in Figure 3, were developed from the seismic hazard assessment, which incorporated all potential sources identified in the study (Geomatrix, 1996). These spectra will be used to help develop the TWRS-P Facility design response spectra.

It may be noted that the horizontal response spectrum in Figure 3 ends at a frequency of 33 Hz. The shape of the horizontal response spectrum for frequencies greater than 33 Hz will be addressed during design when appropriate design response spectra are generated for project use. It will be shown continuing beyond the 33 Hz frequency as a line of constant spectral acceleration at the PGA value.

Figure 3 also shows a "dip" in the vertical response spectra shape. The development of the response spectra in the Geomatrix report (Geomatrix, 1996) considered the effects from many different faults and seismic settings. The lower frequency portion of the response spectra is strongly influenced by the

Cascadia subduction zone and the higher frequency portion is more influenced by nearer seismic events. These two effects, near field and far field, overlap at about the 1 Hz area and result in a small "dip" or concaved area. The union of two effects can result in a concaved zone and be consistent with expected events. In the process of developing design response spectra from the data provided by a seismicity report, however, these concaved areas will be smoothed out, which is conservative.

The spectra of Figure 3 are, as recommended by DOE-STD-1020-94 (DOE 1996a), site-specific and consistent with the estimated earthquake magnitudes and distances and with the soil profile expected at the TWRS-P Facility site. DOE-STD-1020-94 (Appendix C, p. C-20) also allows use of a median standardized spectral shape such as that defined in NUREG/CR-0098 (Newmark and Hall 1978) when a site-specific response spectrum is not available. In this context, it is interesting to note that, as illustrated in Figure 4, the TWRS-P Project equal-hazard spectrum shape closely matches the widely accepted Newmark and Hall (1978) spectrum shape. The modest differences between the two shapes are most likely because the earthquake hazard at the Hanford Site is associated, in general, with smaller and more local earthquakes than the earthquakes considered for the development of the empirical Newmark and Hall spectrum. DOE-STD-1020-94 (DOE 1996a) does not mention the use of the spectra of Regulatory Guide 1.60 (NRC 1973a). Comparison with these spectra would not be appropriate because they define mean plus one standard deviation (rather than median) ground motions, and because they were developed for a deterministic definition of ground motion in the context of nuclear power plant design.

Finally, historical earthquakes were also compared to the DBE as recommended in DOE-STD-1023-95 (DOE 1996c). The largest historical earthquake felt at the Hanford Site is a magnitude 5.7 in Milton Freewater, Oregon, about 90 km (56 miles) from the site. The peak ground acceleration at the site was less than 0.05 g.

4. TWRS-P Project Seismic Design Approach for the DBE

SSCs that have a seismic safety function are analyzed and designed to ensure that they can withstand the loads imposed by the DBE without the loss of ability to perform their seismic safety function. For such DBE-resistant SSCs, the performance categorization evaluation described in Section 2.0 shows that the PC-3 requirements of DOE-STD-1020-94 (DOE 1996a) are applicable for the TWRS-P Project.

The TWRS-P Project approach for the analysis and design of SSCs that need to be DBE-resistant meets the PC-3 requirements of DOE-STD-1020-94 (DOE 1996a). Seismic evaluation is accomplished by dynamic analysis. The recommended approach, which is to perform an elastic dynamic analysis to evaluate the elastic seismic demand, is followed.

Because the TWRS-P Facility location is a soil site and the structure is embedded in the ground, soil-structure interaction (SSI) analysis is performed to obtain seismic demand. The SSI analysis is preformed using the SASSI computer program and site-specific soil properties. Response spectrum compatible time histories are developed for both horizontal and vertical spectra for time history analysis. Seismic excitation is considered in both horizontal directions as well as the vertical direction simultaneously. The combined response is obtained by combining the three co-directional responses by the methods suggested in ASCE 4. Site-specific dynamic soil properties and damping values meeting those in Table 2-3 of DOE-STD-1020-94 (DOE 1996a) are used in the analysis. The SSI results are used to develop seismic loads for design of the structure and in-structure response spectra for design of systems and components. Lateral seismic soil pressure amplitudes are also obtained from the SSI analysis.

The possibility exists that the NRC may replace the DOE as the TWRS-P Project regulator at some future date. Consequently, a review was performed of the NRC's seismic requirements for nuclear power plants contained in Regulatory Guide 1.61 (NRC 1973b) and Standard Review Plan 3.7.2 (NRC 1989) to identify differences with the DOE PC-3 criteria. Subsequent evaluations indicated that it would be practicable to meet these NRC requirements along with the DOE PC-3 requirements. Accordingly, the TWRS-P Project seismic approach was modified as follows:

- Credit for inelastic energy absorption, as allowed by DOE-STD-1020-94 (DOE 1996a), is not taken even though the reinforced concrete structures will be detailed to ensure ductile behavior

- Damping values per Regulatory Guide 1.61 (NRC 1973b) are used for electrical cabinets and other equipment

- Damping values per ASME Code Case N-411, which are acceptable to the NRC, are used for piping.

Each of the above changes is conservative (or consistent) with respect to the seismic design of DBE-resistant SSCs.

Table 2 summarizes the resulting TWRS-P Project seismic design approach and includes the corresponding DOE and NRC requirements for comparison.

In addition to the information contained in Table 2, the RU, in the Level 1 and Topical Meetings, requested additional detail concerning the TWRS-P Project seismic design approach. The related document identified in Section 1.0 ("TWRS-P Facility Seismic Design Criteria") will provide this information, portions of which are listed below. It should be noted that this information is preliminary and may be subject to minor changes in the seismic design criteria document.

- The seismic design response spectra will be based on the Geomatrix report.

- One acceleration time history will be developed for each of the three orthogonal directions. These time histories will satisfy either the NRC (SRP 3.7.1) or the ASCE 4 enveloping criteria, which are very similar.

- Variation of ground motion amplitude and frequency content with depth will be considered for embedded structures per ASCE 4-98 (draft).

- Lateral soil pressure will be developed from the SSI model.

- Load combinations will be consistent with consensus codes such as ACI 349-85 for reinforced concrete.

- Reinforced concrete strength will be developed according to ACI 318-95.

- Equipment with seismic safety functions will be qualified by testing and/or analysis.

- Interaction of seismically qualified and unqualified SSCs will be considered.

- Reinforcing steel will be detailed to ensure ductile behavior.

Finally, seismic events at levels higher than the DBE could credibly occur. Although such events have a relatively low frequency of occurrence, they must still be evaluated. This is because the TWRS-P Project radiation exposure standards given in the SRD (BNFL Inc. 1998a) include standards for accidents with frequencies of occurrence down to 10^{-6} per year. The related document identified in Section 1.0 ("Approach for Ensuring Compliance with the TWRS-P Project Radiation Exposure Standards Under Earthquake Conditions") addresses this aspect of the seismic design.

5. DOE RU Comments and Questions

As discussed in Section 1.0, the RU has provided a number of written comments and questions related to the seismic design of the TWRS-P Facility.

Responses (or cross references) to these comments and questions are given in Tables 3 through 6 as follows:

Table 3 Preliminary questions concerning the BNFL seismic design approach, sent by the RU following the 12/3/98 Level 1 Meeting

Table 4 Preliminary questions concerning the Geomatrix Report and dynamic analysis, sent by the RU following the 12/3/98 Level 1 Meeting

Table 5 Post meeting RU comments, from the RU meeting minutes of the 12/14/98 Topical Meeting

Table 6 Post meeting RU comments, from the RU meeting minutes of the 1/7/99 meeting with Geomatrix Consultants

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Table 1. Cost Estimate Details for Changing DBE Basis from PC-3 to PC-4{ TC "1. Cost Estimate Details for Changing DBE Basis from PC-3 to PC-4" \f T }

TWRS-P ROM STUDY ESTIMATE (ST-01A)

Design Basis Earthquake (DBE) - Cost Impact of change from PC3 to PC4 (PGA increase from 0.24g to 0.44g)

	ROM Estimate ($US)							
Facilities and Systems Impacted	Materials (M)	Labor (L)	S/C (S)	Total	Materials (M)	Labor (L)	S/C (S)	Total
Structures								
Process Building Structures (excl. LAW)	30,286,200	32,444,740	-	62,730,940	50%	40%		28,120,996
Exhaust Stack - Foundation	110,000	140,000	-	250,000	50%	40%		111,000
Exhaust Stack	550,000	220,000	-	770,000	50%	40%		363,000
Total Stack Structure	660,000	360,000		1,020,000	100%	80%		474,000
Diesel Building Structure	100,000	240,000	-	340,000	50%	40%		146,000
Total Impact to Structure - Direct Costs	31,046,200	33,044,740	-	64,090,940				28,740,996
Tanks, Vessels & Equipment								
Cs Ion Exchange Columns (4)	282,740	6,580	-	289,320	50%	50%		144,660
Cs Eluate Receipt Vessels (2)	423,120	6,580	-	429,700	50%	50%		214,850
Cs Recovery Product Tank	60,844	1,680	-	62,524	50%	50%		31,262
HLW Receipt Tanks (3)	2,952,000	59,400	-	3,011,400	50%	50%		1,505,700
HLW Ultrafiltration Feed Vessel	355,880	6,580	-	362,460	50%	50%		181,230
Sr/TRU Precipitate Vessel	1,044,680	17,530	-	1,062,210	50%	50%		531,105
HLW Feed Blending Vessels (2)	150,880	2,960		153,840	50%	50%		76,920
Chemical Storage Tanks (3)	30,000	4,800	-	34,800	50%	50%		17,400
S/T Tanks & Vessels	5,300,144	106,110		5,406,254				2,703,127
Diesel Generators & Electrical Equipment	957,000	326,000	-	1,283,000	100%	50%		1,120,000
S/T Tanks, Vessels & Equipment	6,257,144	432,110		6,689,254				3,823,127
Other Critical Systems								
Process Bldg C5 Ventilation:								
C5 Ventilation System - Ductwork (incl. dampers)	-	-	418,000	418,000			50%	209,000
HEPA Exhaust Filters 3,000 cfm ea, 10 units/bank	3,600,000	105,000	-	3,705,000	50%	50%		1,852,500
Allow for controls at 10% ductwork & dampers	-	-	41,730	41,730			10%	4,173
Hangers, supports @ 5m	-	-	3,000	3,000			50%	1,500
S/T C5 Ventilation System	3,600,000	105,000	462,730	4,167,730				2,067,173
Diesel Generator Systems								
Electrical Bulks	115,000	217,000	-	332,000	50%	50%		166,000
Mechanical Equipment	130,000	43,000	250,000	423,000	100%	50%		151,500
Piping	16,000	53,000	-	69,000	50%	50%		34,500
Instrumentation and Control	31,000	58,000	-	89,000	10%	10%		8,900
HVAC	17,000	4,000	-	21,000	50%	50%		10,500
Total Diesel Generator Bldg. Systems	309,000	375,000	250,000	934,000				371,400
Waste Transfer Lines from DST	830,000	1,500,000	64,000	2,394,000	15%			124,500
Total Direct Costs	42,042,344	35,456,850	776,730	78,275,924	21,261,772	13,650,751	214,673	35,127,196
Distributables - Labor		@18% of direct labor				29,574		29,574
Distributables - Materials		@20% of direct labor			41,420			41,420
Taxes, Freight, Insurance, Spare Parts		@ 10% of direct costs			3,512,720			3,512,720
Field non-manual costs		@ 14% of direct costs				4,917,807		4,917,807
Total Field Costs								43,628,717
Project Mgmt and A/E Costs		@ 35% of direct costs						15,270,051
Total Estimate								58,898,768
Total Estimated Cost Impact (w/25% contingency)								73,623,460

Table 2. Comparison of Seismic Design Requirements{ TC "2. Comparison of Seismic Design Requirements" \f T }

Item	DOE DOE-STD-1020-94 PC-3 SSCs	NRC Regulatory Guide 1.61 and SRP 3.7.2	TWRS-P Design Criteria
Method of Analysis	Dynamic	Dynamic	Dynamic
Inelastic energy absorption factor, F_{μ}	1.0 through 3.0	1.0	1.0
Maximum material damping value for soil (% of critical)	15	15	15
Damping values for SSCs (% of critical):	(Response Level 2)		
• Reinforced concrete structures	7	7	7
• Bearing bolted steel structures	7	7	7
• Friction bolted steel structures	4	7	4
• Welded steel structures	4	4	4
• Piping	5	Per ASME Code Case N-411; see Note (3)	Per ASME Code Case N-411
• Pumps, motors, and instrument racks	3	3	3
• Electrical cabinets and other equipment	4	3	3
• Liquid containing metal tanks - impulsive mode	3	Not specified	3
• Liquid containing metal tanks - sloshing mode	0.5	Not specified	0.5
Soil-structure interaction	Yes	Yes	Yes
Development of in-structure response spectra	Yes	Yes	Yes
Consideration of the three components of earthquake motion	Yes	Yes	Yes
Combination of modal responses	Note (1)	Note (1)	Note (2)
Interaction with non-seismic structures	Yes	Yes	Yes
Effects of parameter variation on in-structure response spectra	Yes	Yes	Yes
Methods used to account for torsional effects	Yes	Yes	Yes
Determination of structure overturning moments	Yes	Yes	Yes

Notes:
(1) Only applicable if Response Spectra Analysis Method (RSAM) is used.
(2) Not applicable because Time History Analysis Method to be used in lieu of RSAM.
(3) ASME Code Case N-411 damping values for piping are acceptable to the NRC.

Table 3. Preliminary Questions Concerning BNFL Seismic Design Approach (sent by the RU following the 12/3/98 Level 1 Meeting){ TC "3. Preliminary Questions Concerning BNFL Seismic Design Approach" \f T }

No.	Question/Comment	Response
1	How will the design methodology for natural phenomena hazards ensure that the dose standards are met? For example, for those SSCs that are assigned to Performance Category 3, how will the design methodology ensure that for extremely unlikely events, Safety Criteria 2.0-1 radiation dose standards are still met? (The design basis return period for performance category 3 SSCs is 2000 years.)	This question is addressed in the related document *Approach for Ensuring Compliance with the TWRS-P Project Radiation Exposure Standards Under Earthquake Conditions*.
2	How will DOE-STD 1020 and 1021, the implementing standards for SC 4.1-3 and -4, be interpreted, given that these standards use non-TWRS-P contract DOE terminology such as “safety significant” SSCs? (Conventionally, DOE-STD 1020 and 1021 are used in combination with DOE Order 420.1, DOE-STD 1022, DOE-STD-1023, and related Implementation Guides. BNFL has not found it appropriate to adopt these standards, and the RU has accepted that determination. However, the resulting standards set is ambiguous, to some degree.) Please relate the schedule for resolution of these ambiguities to the overall NPH design methodology and schedule.	This question is addressed in the related document *Applicability of DOE Documents to the Design of the TWRS-P Facility for Natural Phenomena Hazards.*
3	Neither the November 19 transmittal of information for the December topical meeting nor the May 1, 1998, seismic design criteria information discuss the design approach or criteria to be used for seismic qualification of SSCs, including tanks. When and how does BNFL intend to address this subject? For information, BNL report 52361, <u>Seismic Design and Evaluation Guidelines for the Department of Energy High-Level Waste Storage Tanks and Appurtenances</u> provides one method for tank seismic design analysis previously approved by DOE on other contracts.	The BNL report cited in the question will be considered by the Project. This question will be addressed in the related document *TWRS-P Facility Seismic Design Criteria.*

Table 3. Preliminary Questions Concerning BNFL Seismic Design Approach (sent by the RU following the 12/3/98 Level 1 Meeting){ TC "3. Preliminary Questions Concerning BNFL Seismic Design Approach" \f T }

No.	Question/Comment	Response
4	Please outline the seismic design approach/criteria to be used. Include topics in this discussion such as SSC performance categorization, computer codes and code validations planned, seismic detailing methodology, seismic interactions, in-structure response, structural analysis and design (and any differences in treatment between safety design class and safety design significant SSCs), soil structure interaction, design basis spectra, and development of design basis time histories. Clarify the extent of BNFL's planned commitment to ASCE 4.	Section 4.0 of this report provides some of the information requested by this question. This comment will be fully addressed in the related document *TWRS-P Facility Seismic Design Criteria.*
5	What is the schedule for development of each of the topics described in Question 4?	The related document, *TWRS-P Facility Seismic Design Criteria*, is scheduled to be issued at the end of May 1999.
6	Provide the calculation that was performed to estimate the increase in cost of the facility due to an increase in performance category from PC 3 to PC [4]. Provide any other calculations that estimate the variation of cost with peak ground acceleration. Indicate any known limitations and assumptions in the cost model.	Cost estimate details are shown in Table 1. There are no other project calculations that estimate the variation of cost with peak ground acceleration. The cost model is based primarily on the conceptual design of the facility and is therefore limited by the lack of design information/detail.
7	How does BNFL intend to approach the hazard analysis and resulting control strategies for a natural phenomena induced fire? For example, earthquake initiated fires are relatively predictable, given a severe earthquake, and the presence of combustible cables and electrical energy.	The seismic radiological exposure consequence analyses performed for the Part A ISAR and for the Companion Report considered the potential impacts of fires on public and worker radiation exposures. The analyses found that only minimal amounts of flammable material would be expected in the areas where significant quantities of radioactive material were present; hence, there would be no enhancement of the radioactive source term due to a fire. Also, because the analyses assumed complete structural and equipment failure, loss of power or control functions due to a fire would not result in more severe consequences than calculated. The TWRS-P Project approach to fire protection, including seismically induced fires, was presented in the submittal that was the basis for the February 1999 Topical Meeting.

Table 4. Preliminary Questions Concerning the Geomatrix Report & Dynamic Analysis (sent by the RU following the 12/3/98 Level 1 Meeting){ TC "4. Preliminary Questions Concerning the Geomatrix Report & Dynamic Analysis" \f T }

No.	Question/Comment	Response
1	How will phasing of three-dimensional accelerogram, a(x,y,z), be accomplished? Will ASCE-4 be used?	Section 4.0 of this report provides some of the information requested by this question. This question will be fully addressed in the related document *TWRS-P Facility Seismic Design Criteria.*
2	What is the range of estimated fundamental periods of the site before and during earthquake loading?	This question is addressed in the related document *Validation of the Geomatrix Hanford Seismic Hazard Report for Use on the TWRS-P Project.*
3	What are the predominant periods of response of these three-dimensional structures, tanks, and vessels (for example Ti, with i=0 to 12)?	Expected structural frequencies will be 4 Hz or greater. Expected sloshing frequency in tanks will be 1 Hz or less.
4	How were recurrence relationships determined for magnitudes greater than the empirical databases (see Figures 3-3, 3-5, 3-14, 3-15, 3-24, and 3-26)?	This question is addressed in the related document *Validation of the Geomatrix Hanford Seismic Hazard Report for Use on the TWRS-P Project.*
5	Why do the two significant earthquakes (M=6.5 and M=7.0) plot above the recurrence relationship (Figure 3-35)?	This question is addressed in the related document *Validation of the Geomatrix Hanford Seismic Hazard Report for Use on the TWRS-P Project.*
6	How do the PGA and Spectra for the design basis and beyond design basis earthquakes compare to USGS results (Frankel et al. 1996), site-specific uniform hazard spectra and a deterministic approach (such as Krinitzsky 1995, Abramson & Silva), including sigma bounds and mean and median values?	This question is addressed in the related document *Validation of the Geomatrix Hanford Seismic Hazard Report for Use on the TWRS-P Project.*
7	How do the input parameters in your probabilistic seismic hazard analysis compare to USGS values (Frankel et al. 1996)?	This question is addressed in the related document *Validation of the Geomatrix Hanford Seismic Hazard Report for Use on the TWRS-P Project.*
8	Are there any new geological or seismologic data that postdate the Geomatrix (1996) report that are significant?	This question is addressed in the related document *Validation of the Geomatrix Hanford Seismic Hazard Report for Use on the TWRS-P Project.*
9	How do the attenuation relationships used for subduction-zone earthquakes compare to the empirical databases in the range of distances appropriate for this site?	This question is addressed in the related document *Validation of the Geomatrix Hanford Seismic Hazard Report for Use on the TWRS-P Project.*
10	How were the peak accelerations for subduction-zone earthquakes scaled in the site-specific site response analyses (Appendix A)?	This question is addressed in the related document *Validation of the Geomatrix Hanford Seismic Hazard Report for Use on the TWRS-P Project.*

Table 4. Preliminary Questions Concerning the Geomatrix Report & Dynamic Analysis (sent by the RU following the 12/3/98 Level 1 Meeting){ TC "4. Preliminary Questions Concerning the Geomatrix Report & Dynamic Analysis" \f T }

No.	Question/Comment	Response
11	How will the design spectra be determined and modified from uniform hazard and deterministic spectra?	The design response spectra will be determined from the equal hazard curve in the Geomatrix Report. The spectra will be defined for frequencies higher than 33 Hz because the Geomatrix report did not specify values. The spectra may be simplified by using a conventional standard shape such as Newark and Hall, or retain the site-specific shape given in the Geomatrix report but use fewer straight-line segments. The selected shape will be incorporated in the related document *TWRS-P Facility Seismic Design Criteria.*
12	How does historical seismicity relate to geological structure?	This question is addressed in the related document *Validation of the Geomatrix Hanford Seismic Hazard Report for Use on the TWRS-P Project.*
13	How was “ground truthing,” aerial and field reconnaissance, of input parameters to probabilistic seismic hazard analysis accomplished? Where is it documented?	This question is addressed in the related document *Validation of the Geomatrix Hanford Seismic Hazard Report for Use on the TWRS-P Project.*
14	Will site-specific site response analyses be conducted with suites of both artificial and scaled recorded accelerograms? How many dimensions would be used (1-, 2-, or 3-dimensional deposit and 1-, 2-, or 3-dimensional accelerograms)? How will you select appropriate rock outcrop motions?	This question is addressed in the related document *Validation of the Geomatrix Hanford Seismic Hazard Report for Use on the TWRS-P Project.*

Table 5. Post Meeting RU Comments (from the RU meeting minutes of the 12/14/98 Topical Meeting){ TC "5. Post Meeting RU Comments (12/14/98 Topical Meeting)" \f T }

No.	Question/Comment	Response
1	The evaluation of beyond design basis earthquake effects on RESW standards should be completed. This includes the identification of any design modifications that may be required to meet the RESW standards.	The related document, *Approach for Ensuring Compliance with the TWRS-P Project Radiation Exposure Standards Under Earthquake Conditions*, describes the approach to be taken. Upon approval by the RU, this approach will be implemented and any design modification that may be required to meet the radiation exposure standards will be identified.
2	SSCs that will be designed to other than PC-3 criteria should be identified and the associated rationale should be included.	As the design evolves, the hazard evaluation process will identify those SSCs that have seismic safety requirements (and therefore need to be designed to PC-3 criteria). The risk reduction potential and cost-effectiveness of designing to beyond PC-3 requirements will be evaluated on a case-by-case basis. The results of this evaluation will be documented in the TWRS-P Project PSAR.
3	Identify documents that will be used to develop the seismic design, specifically what version of ASCE-4 will be used?	ASCE 4-98 (draft) will be used. This question will be fully addressed in the related document *TWRS-P Facility Seismic Design Criteria.*
4	Resolve conflicting seismic criteria (PGA) in the Hanford 200 East area (0.24g) verses the 200 West area (0.26g).	This comment is discussed in Section 3.0 of this report. In summary, the conflict arises because a Hanford Site administrative procedure, HNF-PRO-97 (Numatec 1997), applies the more conservative 200 West Area seismic criteria uniformly to the 200 East, 200 West, and 100 Areas for consistency of use by Hanford Site contractors. BNFL Inc. has elected to address the conflict by using the 0.26g value for the DBE peak ground acceleration for the TWRS-P Project. This decision is based on several factors including consistency within the 200 Area of the Hanford Site, an increased margin of safety, and low differential cost.
5	Research the availability of recorded site seismic data to compare with Geomatrix Report.	This comment is addressed in the related document *Validation of the Geomatrix Hanford Seismic Hazard Report for Use on the TWRS-P Project.*
6	Evaluate how the maximum magnitudes in the USGS report (Franker, et al, 1996) compare to the range of magnitudes in the Geomatrix report.	This comment is addressed in the related document *Validation of the Geomatrix Hanford Seismic Hazard Report for Use on the TWRS-P Project.*
7	Explain “dip” in the vertical response spectra shape.	The development of the response spectra in the Geomatrix report considered the effects from many different faults and seismic settings. The lower frequency portion of the response spectra is strongly influenced by the Cascadia subduction zone and the higher frequency portion is more influenced by nearer seismic events. These two effects, near field and far field, overlap at about the 1 Hz area and result in a small “dip” or concaved area. The union of two effects can result in a concaved zone and be consistent with expected events. In the process of developing design response spectra from the data provided by a seismicity report, however, these concaved areas will be smoothed out, which is conservative.

Table 5. Post Meeting RU Comments
(from the RU meeting minutes of the 12/14/98 Topical Meeting){ TC "5. Post Meeting RU Comments (12/14/98 Topical Meeting)" \f T }

No.	Question/Comment	Response
8	The second sentence of the Introduction of the BNFL seismic submittal dated November 19, 1998 should mention the environment as one of the areas of concern in addition to concern for worker and public safety.	The introduction to this report (Section 1.0) has been modified accordingly.
9(1)	The Crystalline Basement tectonic model has a significant impact on design motions. Scientific data and analysis of the rift, block and uniform models are lacking. High subjective weight (0.8) is given to the uniform model which results in the least "probabilistic" contribution. A more scientific basis or at least a more sensitive analysis of these subjective weights should be considered.	This comment is addressed in the related document *Validation of the Geomatrix Hanford Seismic Hazard Report for Use on the TWRS-P Project.*
9(2)	Yakima fold sources are affected by whether they are active, coupled or segmented. The activity should have more scientific basis. Faults that are currently uncoupled and segmented may become coupled and segmented.	This comment is addressed in the related document *Validation of the Geomatrix Hanford Seismic Hazard Report for Use on the TWRS-P Project.*
9(3)	Coupling should not reduce recurrence rates. Why are alternative assumptions, reality checks and sensitivity analysis not considered?	This question is addressed in the related document *Validation of the Geomatrix Hanford Seismic Hazard Report for Use on the TWRS-P Project.*
9(4)	The Cascadia interface contribution may be too small due to insufficient energy attenuation and site response. However, its impact could be more significant in the long-period range. Has this been analyzed?	This question is addressed in the related document *Validation of the Geomatrix Hanford Seismic Hazard Report for Use on the TWRS-P Project.*
9(5)	Would one conclude that the Cascadia interslab and Shallow Basalt sources are relatively unimportant to the overall hazard?	This question is addressed in the related document *Validation of the Geomatrix Hanford Seismic Hazard Report for Use on the TWRS-P Project.*
9(6)	Attention to the overall model and details is important since the probabilistic seismic hazard analysis is being used to specify an <u>absolute</u> design ground motion, rather than to develop a <u>relative</u> number.	This comment is addressed in the related document *Validation of the Geomatrix Hanford Seismic Hazard Report for Use on the TWRS-P Project.*

Table 6. Post Meeting RU Comments (from the RU meeting minutes of the 1/7/99 meeting with Geomatrix Consultants){ TC "6. Post Meeting RU Comments (1/7/99 Meeting with Geomatrix)" \f T }

No.	Question/Comment	Response
1	The geological basis for the subjective weights assigned to different fault models in the PSHA logic tree should be elaborated, to provide a clearer logical basis for the weights chosen. For example, the coefficients assigned for coupled vs. uncoupled fault segments, crystalline basement fault characteristics, and Yakima fold models should be elaborated.	This comment is addressed in the related document *Validation of the Geomatrix Hanford Seismic Hazard Report for Use on the TWRS-P Project.*
2	Sensitivity calculations to show the effect of different fault model weighting factors on the peak ground acceleration and like seismic spectra should be presented. Representative recurrence intervals of interest, such as 2000 and 10000 year recurrences, are acceptable, rather then a comprehensive sensitivity study.	This comment is addressed in the related document *Validation of the Geomatrix Hanford Seismic Hazard Report for Use on the TWRS-P Project.*
3	The expert reviews regarding the Geomatrix study collected during and after its preparation should be provided to the RU. (Subsequent to the meeting, BNFL has provided this information to the RU.)	Available comments on the Geomatrix Report were forwarded to the RU on January 20, 1999. No further response is required.
4	BNFL will provide an outline of the BNFL/Bechtel evaluation report of the Geomatrix report to the RU once it is available.	An outline of the BNFL evaluation of the Geomatrix Report was forwarded to the RU on January 29, 1999. No further response is required.
5	Figure 4-10 of the Geomatrix study shows the peak ground acceleration attenuation function below the data in the 300-400 FM range. Yet this distance is the range of interest for the TWRS-P site. The effect of using an attenuation estimate in this range that better predicts the data on PGA, and spectra should be discussed.	This comment is addressed in the related document *Validation of the Geomatrix Hanford Seismic Hazard Report for Use on the TWRS-P Project.*
6	Scoping study should evaluate whether a significant basin effect may exist for the TWRS-P site. The study should consider current research (Franker, Larsen), and factors such as edge effect, slope of the basin, and basin material.	This comment is addressed in the related document *Validation of the Geomatrix Hanford Seismic Hazard Report for Use on the TWRS-P Project.*
7	The geotechnical SHAKE code runs that were previously performed by Geomatrix to confirm the predominant site periods, empirical relations such as the frequency dependence of attenuation, and the local soil response spectra should be reviewed to confirm the data has been adequately reflected in the Geomatrix report.	This comment is addressed in the related document *Validation of the Geomatrix Hanford Seismic Hazard Report for Use on the TWRS-P Project.*
8	A detailed bibliography of data reports that support the Geomatrix 1996 report will be provided in the BNFL/Bechtel evaluation of the Geomatrix report.	This comment is addressed in the related document *Validation of the Geomatrix Hanford Seismic Hazard Report for Use on the TWRS-P Project.*
9	The records from strong motion instruments in the Hanford vicinity will be reviewed, and the resets of this review provided in the BNFL/Bechtel evaluation of the Geomatrix report.	This comment is addressed in the related document *Validation of the Geomatrix Hanford Seismic Hazard Report for Use on the TWRS-P Project.*

Figure 1. Mean Seismic Hazard Curve for the 200 East Area{ TC "1. Mean Seismic Hazard Curve for the 200 East Area" \f F }

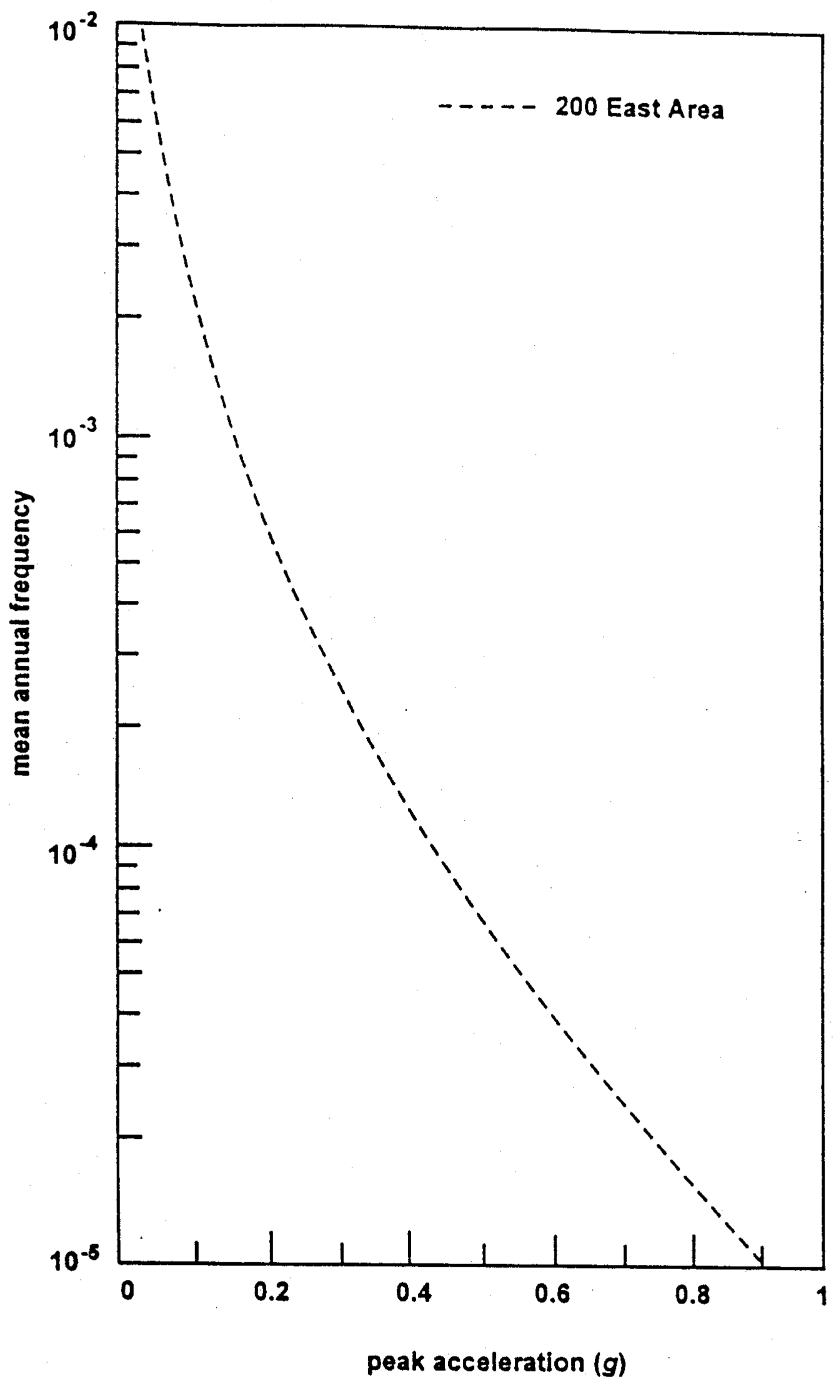

Figure 2. Contribution of Individual YFB Folds to the Mean Seismic Hazard{ TC "2. Contribution of Individual YFB Folds to the Mean Seismic Hazard" \f F }

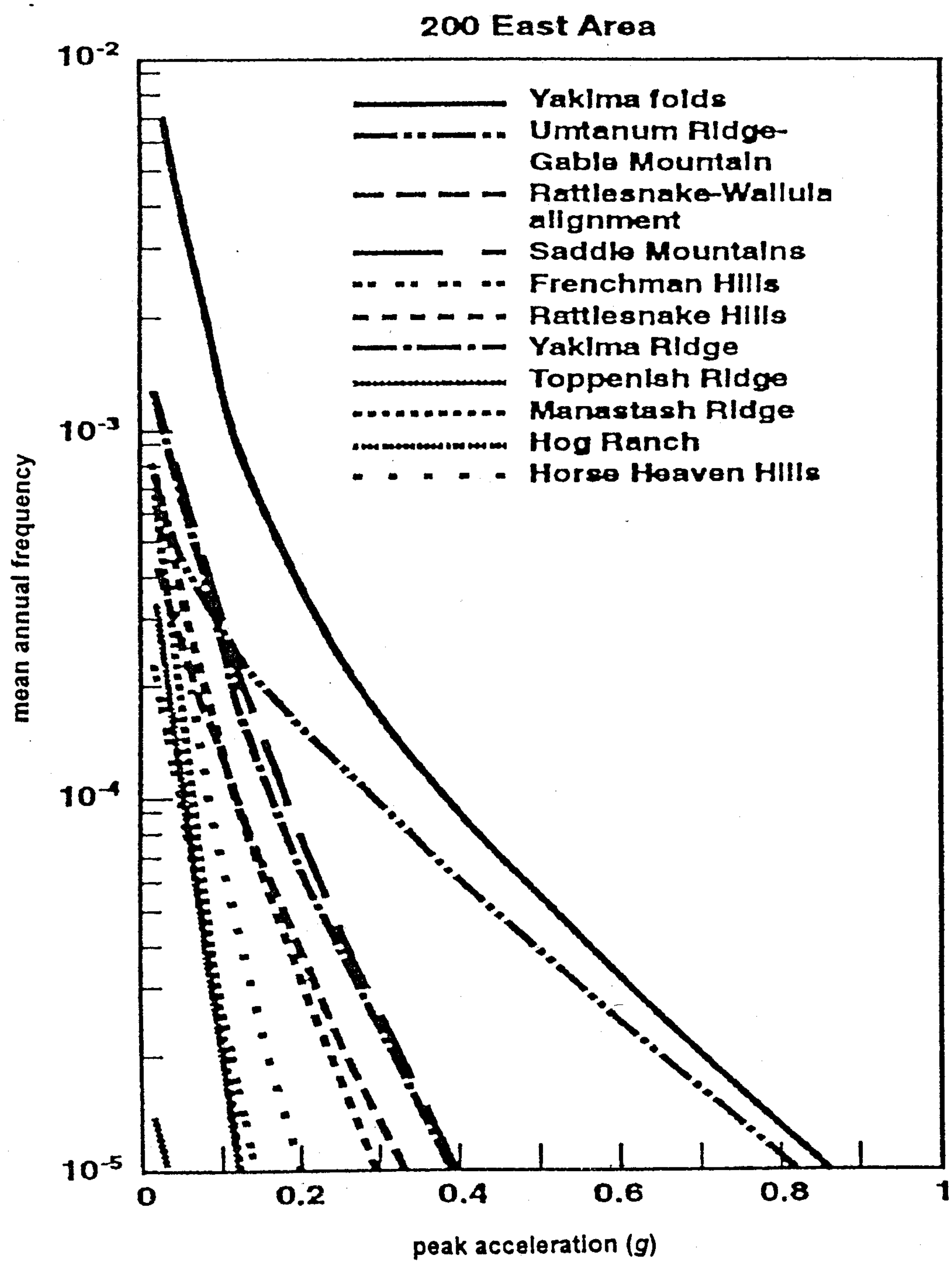

Figure 3. 200 Area 2,000-Year Return Period Equal Hazard Response Spectra{ TC "3. 200 Area 2,000-Year Return Period Equal Hazard Response Spectra" \f F }

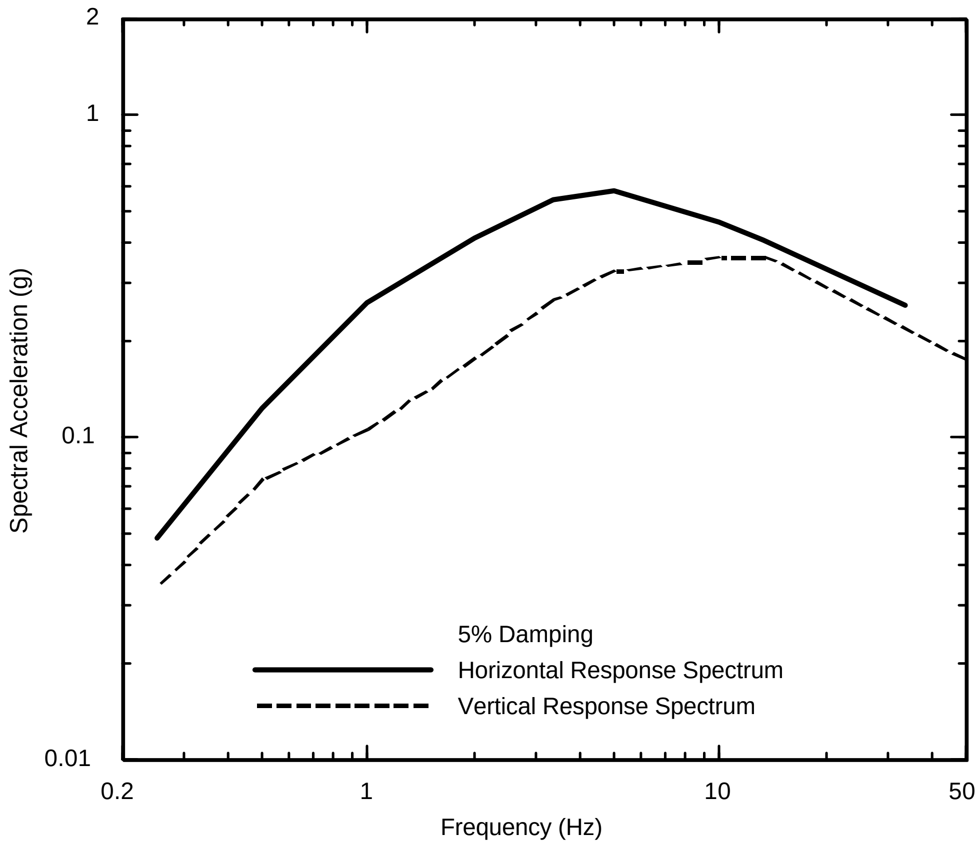

Figure 4. Comparison of the Horizontal 200 Area 2,000-Year Return Period and the Newmark & Hall Competent Soil, Median Normalized Response Spectral Shapes{ TC "4. Comparison of the Horizontal 200 Area 2,000-Year Return Period and the Newmark & Hall Competent Soil, Median Normalized Response Spectral Shapes" \f F }